This year's theme was Learning Earth's Shapes and Colors. 149 topics were arranged into 7 sections, including:

- **Applications of Remote Sensing**
- **Mission and Programs**
- **Geoscience, Modeling, & Processing**
- **Data Processing & Algorithms**
- **Electromagnetic Problems**
- **Instrumentation & Techniques**
- **Policy, Societal Issues, & Education Initiatives**

An Ultra-wideband Radar for Measurements of Snow Thickness Over Sea Ice

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Abstract— **Snow cover of variable thickness exists on sea ice with thickness fluctuations in the range from less than a few centimeters to several meters depending on snow drifts and ice type. Snow largely controls the thermal and electrical properties of a sea ice cover. Because of its low thermal conductivity, it effectively insulates the sea ice surface from cold polar air and modifies the heat flux between the atmosphere and ocean. It also changes the sea ice albedo. Additionally, thick snow cover acts as a mechanical load and can depress the ice surface below sea level, causing the ice floe to be flooded with sea water. Thus accurate knowledge of snow thickness on sea ice is essential for determining the overall heat budget in the polar regions, which in turn can impact global ocean circulation and climate.**

We developed an ultra-wideband radar for measuring snow thickness. It operates over the frequency range from 2-8 GHz in FM-CW mode. We used a phase-locked YIG oscillator to generate a very linear 2-8 GHz chirp by using a low-frequency (5-20 MHz) digital chirp generator as a reference signal for the phase detector. We also constructed a receiver with a large dynamic range and fast settling time. The received signal was digitized using a 12-bit A/D converter and stored for further processing. We also developed simple models to simulate radar performance. We modeled snow as a multi-layered media and sea ice as dielectric half-space, and performed extensive simulations using snow geophysical data collected during Antarctic cruises to optimize radar performance.

We evaluated the radar's performance by measuring its response to point targets such as a delay line and corner reflectors. With the Hanning window function, the measured radar range resolution is about 3.75 cm. We collected data on snow-covered ground in conjunction with measurements of snow parameters such as density, particle size, and roughness. The results from these measurements show that we can clearly delineate returns of the snow-air and snow-ground interfaces for 6-cm-thick dry snow.

Keywords- wideband; radar; FM-CW; snow; sea ice

I. INTRODUCTION

Snow accumulation on sea ice is highly variable in time and in space. Total snow cover on sea ice depends on the age of the sea ice, the dynamics of ridge formation and associated snow drifts, and the passage of storms. The thickness can reach more than 1 m before melting in the spring and summer. Snow has a thermal heat conductivity that is an order of magnitude less than that of sea ice and thus, enhances the insulating effect of sea ice and subsequently ice production and ocean-to-atmosphere heat exchange [1,2]. It also alters sea ice albedo, changing the radiation balance. Furthermore, a thick snow cover acts as a mechanical load and depresses the ice surface below sea level, causing the ice floe to be flooded with sea water; a frequent event in the Southern Ocean. This alters the thermal and electrical properties of the snow-ice system. An accurate knowledge of snow thickness distribution on sea ice is essential for determining the overall heat budget in the polar regions, which in turn can impact global ocean circulation and climate.

Much of the snow thickness data over sea ice are obtained with in-situ measurements at a few locations. These in-situ measurements are sparse and are inadequate for obtaining a good statistical representation of snow cover. Spaceborne sensors are needed for measuring the thickness of snow over sea ice globally. Markus and Cavalieri [3] developed an algorithm for determining snow thickness from satellite passive microwave data using these in-situ measurements, but further testing and validation with extensive data over different regions of the Arctic or Antarctic is needed. It is difficult to collect in-situ data over an area equal to the size of a typical spaceborne radiometer footprint. An ultra-wideband radar with a fine resolution has great potential to obtain an independent estimate of snow thickness. If such a radar can be operated from a low-flying helicopter or aircraft, it can be used to collect data over a large area, enabling the validation of snow thickness algorithms at spatial scales comparable to the satellite measurements.

Using geophysical data of snow collected over sea ice, we constructed an electromagnetic (EM) model of snow-covered sea ice. By combining the EM model with a system model, we simulated radar performance under a variety of conditions. We used the results from these simulations to guide our design and development of an ultra wideband radar. It operates over the frequency range from 2 to 8 GHz with a range resolution of about 4 cm. We constructed the radar such that it can be operated from a sled or low-flying helicopter.